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ABSTRACT

A set of APL (A Programming Language) programs written for use on a time-sharing IBM System/370 computer and used to aid in the teaching of selected econometric concepts is described. The programs involve the simulation of a set of  $n$  observations; of a simple regression model  $Y = A + BX + U$ ; the plotting of the  $Y$  and  $X$  simulated values; the estimation of the regression coefficients  $A$  and  $B$  and their comparison with the true population coefficients; and the plotting of the estimated and true regression lines for comparative purposes. The uses of the programs in teaching the statistical concepts and their applications to econometric problems are described, and sample outputs are shown. (WDR)

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1. Introduction. During the past year four faculty members at State University College (Geneseo), along with about 70 faculty from 15 other undergraduate institutions in New York, participated in a state-wide, 27-month, NSF supported program of experimentation and development of computer assisted instruction (CAI) using primarily APL (A Programming Language).<sup>1</sup> At Geneseo, this program is carried out with an IBM 2741 communications terminal with a telephone link to an IBM/370 155 computer at SUNY-Binghamton, 150 miles away. APL\370 is thus a remote-terminal, time-sharing system which uses this language with IBM System/370 computers. This paper presents some preliminary results of APL\370 in teaching econometrics.

In order to understand the APL\370 system more fully, it is useful to recall that there are two main modes of utilizing a computer: batch processing, and time-sharing processing. In batch processing, computer programs are treated as if they are in a queue waiting to be run. Instructions may be punched on cards (or some other input means such as a terminal), the numerical data that go with the instructions are then added, and the deck of cards are then placed on the card reader to wait in line for processing. In time-sharing mode, the computer inputs data from many users simultaneously (in contrast to batch processing in which one program is read in at a time), keeping up a kind of conversation with them. The users at the terminals slowly interact with the terminal, building up their programs or simply using the system's stored library of programs. Since the computer is extremely fast, the users will seldom have to wait for more than a second to obtain a response from the computer. The APL\370 system is one which provides a high degree of interaction between the user and the terminal, and is often referred to as "an interactive" approach to computer programming.

<sup>1</sup>APL designates the programming language that is the outgrowth of the work of K. E. Iverson, first at Harvard and then at IBM. The name comes from the initials of his book: A Programming Language (New York: Wiley, 1962)

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The power and versatility of APL\ 370 may be realized by means of a wide variety of computer programs. While we will not attempt to classify these programs, they usually can be placed under headings such as games, tutorials, simulations, and problem-solving packages. The problem-solving programs, such as The University of Alberta STATPACK2 package<sup>2</sup>, which is available in the public libraries of most APL systems, and the New Platz Library of Statistical Programs<sup>3</sup>, are now used routinely in teaching economic statistics at SUC (Geneseo). To use these packages the student copies the appropriate program from the library, types in the vector (or matrix) of observations and other data, and upon hitting the return key the results of the statistical analysis, which will include the estimated regression coefficients and their standard errors in a regression program, will be displayed immediately.

2. Obstacles to Teaching Econometrics. Applied econometrics consists primarily in the application of regression analysis to economic data. These data are mainly non-experimental observations—mostly in the form of economic time series—and contain well-known limitations which may make them unsuited for use by the ordinary least squares (OLS) estimating procedure.

In experimental data, for which OLS was initially intended, one attempts to obtain observations which satisfy the assumptions of regression theory. However, in the case of non-experimental data, one attempts to find a theory or model which can best utilize the existing data, or one attempts to evaluate how effectively a given regression model is able to utilize these data. Indeed, many of the problems encountered in teaching econometrics stem from attempts to utilize inadequate empirical data in regression analysis.

How can APL\ 370, with its rapid response and versatility, and its facility for handling arrays, aid in the improvement of teaching effectiveness in econometrics? By using the computer to simulate observations which represent real life data, and by testing various least squares estimating procedures on these data (in particular

<sup>2</sup>Smillie, K. W., STATPACK2: AN APL STATISTICAL PACKAGE. Department of Computer Science, The University of Alberta.

<sup>3</sup>Frins, J. APL: NEW PLATZ LIBRARY OF STATISTICAL PROGRAMS. 4th Ed., 1972, SUC (New Platz).

OLS), the teaching of empirical econometrics should be greatly facilitated.

3. Simulation of Economic Observations. The simulations used in the programs to be discussed shortly involve stochastic processes and are called Monte Carlo simulations. An essential feature of these simulations is the generation of random numbers. Fortunately, many APL libraries contain several random number distributions and generation routines that draw random numbers according to certain probability distributions. The routines used in these programs are contained in the School of Advanced Technology (SAT) Library at SUNY-Binghamton.<sup>4</sup>

The advantage of APL\370 in Monte Carlo simulation is its rapid response and simplicity of use, but it should be mentioned that one disadvantage of this system is that it cannot do large simulations easily. However, for instructional purposes, this limitation is not serious.

Two programs, out of six that have been written and evaluated by a class of 16 students in econometrics, will be discussed. These programs involve the simulation of a set of  $n$  observations (sample size of  $n$ ) of a simple regression model  $Y = A + BX + U$ ; the plotting of the  $Y$  and  $X$  simulated values; the estimation of the regression coefficients  $A$  and  $B$  and their comparison with the true population coefficients; and the plotting of the estimated and true regression lines for comparative purposes. The remaining programs, not discussed here, consist of Monte Carlo simulations of various multiple regression models.

Among the objectives of these two programs are: (1) To impress the student with the fact that a sample of observations from economic time series is, in reality, a random sample from some hypothetical population; (2) That the estimated regression line is an empirical representation of the true regression line; (3) As the size of sample is increased, the estimated regression coefficients approximate more closely the true regression coefficients; (4) To emphasize the role played by the random  $U$  term in regression models; and (5) When the error term  $U$  is autocorrelated (serially

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<sup>4</sup>The generation routines used in these models were written by Professor Peter Weitach of the School of Advanced Technology, SUNY-Binghamton.

correlated), the standard errors of the regression coefficients are increased relative to those of the non-serially correlated models.

Objective (1) is particularly important because textbooks in this field usually omit a worthwhile discussion of the underlying population from which a sample of time series observations is assumed to be drawn. Thus, students often fail to grasp the relationship between the sample that they are working with and the underlying population. However, in the case of experimental data, the student has much less difficulty in relating the sample to the population.

The first regression model to be discussed is:  $Y = 300 + .3X + U$ . In this model,  $Y$  represents family expenditures on consumer durables,  $X$  is family income in dollars, and  $U$  is a random error term normally distributed with mean zero and variance as specified by the user.  $300 + .3X$  is the true component of  $Y$ , and  $U$  is the random component. This model reveals that as family income increases by \$1, a family will spend an additional 30 cents on consumer durables, subject to the random disturbance term  $U$ .

To encourage interaction between user and the computer (or terminal), a number of responses are called for, including five YES and NO responses, as the program is executed. With regard to the numerical inputs, the user is asked to select the sample size and the standard deviation of the  $U$  term. Family income is selected randomly by the computer from a uniform distribution on the interval \$2000 to \$25000, and the  $U$  terms are generated from a normal distribution with mean zero and standard deviation selected by the user. The computer displays these  $U$  terms, the  $n$  income values, the true component of  $Y$ , and finally the generated  $Y$  values. Simulations may be repeated with different sample sizes, income ranges, and different standard deviations.

Space limitations preclude the displaying of the APL programs in their entirety. However, portions of the print outs, beginning with the selection of sample size by the user, are displayed below for sample sizes of 10 and 30. The estimated and true regression lines plotted in the print outs should form straight lines, except for the approximation errors in the PLOT function.

CHOOSE A RANDOM NUMBER BETWEEN 10 AND 30 FOR THE SIZE OF SAMPLE

10

THE 10 FAMILY INCOME VALUES WILL BE SELECTED RANDOMLY FROM THE INTERVAL 2000 TO 25000 AND ARE 19903.2 5065.9 23171.5 9272.6 23691.3 24383.6 7313.9 7526.3 21032.3 12368.7

CONSUMER DURABLE EXPENDITURES Y WILL BE GENERATED BY ASSUMING THAT THE RANDOM ERROR TERM U IS NORMALLY DISTRIBUTED WITH MEAN ZERO AND SPECIFIED VARIANCE. PLEASE SELECT A NUMBER BETWEEN 400 AND 800 FOR THE STANDARD DEVIATION OF U.

3:

500

THE RANDOM ERROR TERM U CORRESPONDING TO YOUR STANDARD DEVIATION ARE 233.3 -1003.8

343.15 738.65 -148.5 -184.35 -1302.7 -86.15 -298 -291.7

THE TRUE COMPONENT OF Y, NAMELY  $300 + 0.3X$ , IS AS FOLLOWS 6270.36 1813.77 7251.45 2081.78

7407.39 7615.08 2435.97 2558.07 6627.69 4190.61

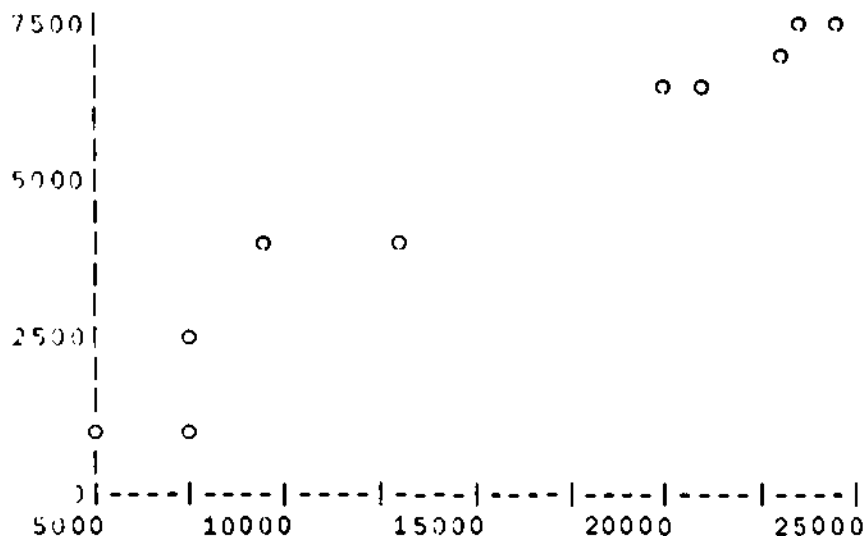
EXPENDITURES ON CONSUMER DURABLES Y ARE OBTAINED BY ADDING THE TRUE COMPONENT TO

THE RANDOM ERROR TERM U

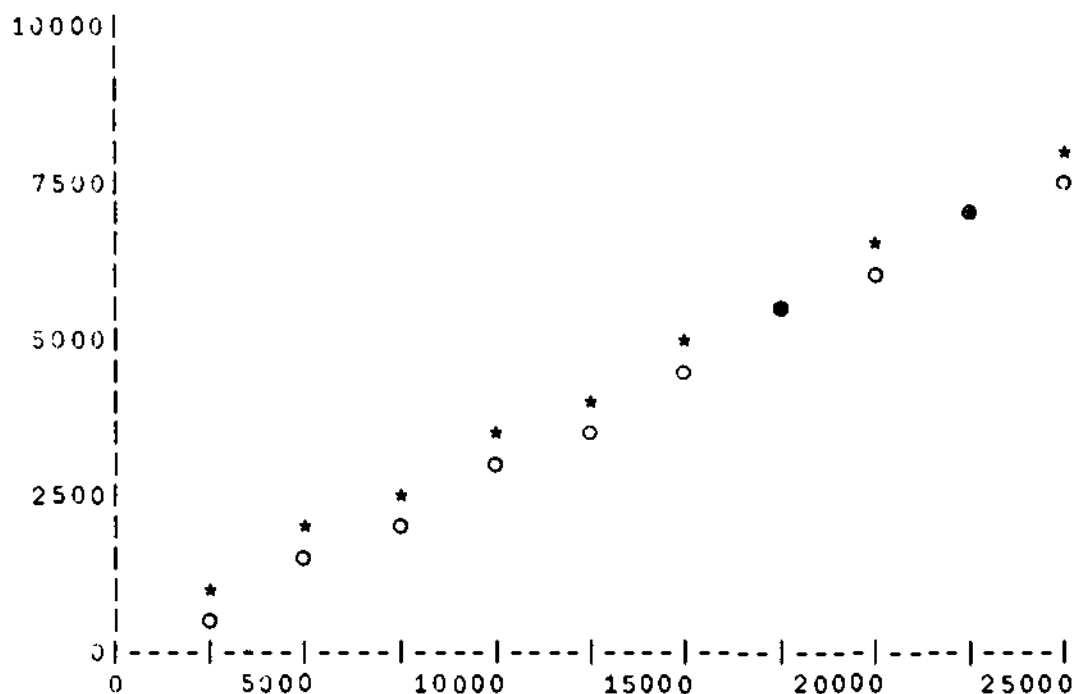
THE ABOVE FOUR SETS OF VALUES ARE SHOWN IN THE FOLLOWING TABLE

X(FAMILY INCOME)	300+.3X	U	Y
19903.2	6270.96	233.3	6504.26
5065.9	1819.77	-1009.8	809.97
23171.5	7251.45	-343.15	6908.3
9272.6	3081.78	738.65	3820.43
23691.3	7407.39	-148.5	7258.69
24383.6	7615.08	-184.35	7430.73
7313.9	2495.97	-1302.7	1193.27
7526.9	2558.07	-86.15	2471.92
21032.3	6627.69	-238	6329.09
12368.7	4190.61	-291.7	3898.91

THE VALUES FOR Y, CONSUMER EXPENDITURES, AND X, FAMILY INCOME, ARE PLOTTED BELOW



THE ESTIMATED REGRESSION LINE, BASED ON THE SIMULATED VALUES OF Y AND X, IS  $7304.5856596 + 0.3217102552X$ . THIS LINE IS SOMEWHAT DIFFERENT FROM THE TRUE LINE  $300 + 0.3X$ . BOTH LINES ARE COMPARED IN THE FOLLOWING GRAPH WHERE THE CIRCLES REPRESENT THE ESTIMATED LINE AND \* THE TRUE LINE



IF YOU WOULD LIKE TO SIMULATE ANOTHER SET OF OBSERVATIONS WITH A DIFFERENT SET OF INPUT VALUES, PLEASE TYPE YES. OTHERWISE TYPE NO.



ON 23 JULY 2000 VALUES WILL BE SELECTED RANDOMLY FROM THE INTERVAL 2000 TO 25000

VALLEY 100% WIDE OF SUBSIDIZED AGRICULTURE	VALLEY 100% WIDE OF SUBSIDIZED AGRICULTURE	VALLEY 100% WIDE OF SUBSIDIZED AGRICULTURE	VALLEY 100% WIDE OF SUBSIDIZED AGRICULTURE	VALLEY 100% WIDE OF SUBSIDIZED AGRICULTURE				
471 APR 21000	6	11975.1	4796.9	15827.6	12407.5	16354.3	6731.1	10752.1

Year	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100
1967	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100

PLEASE SELECT A NUMBER BETWEEN 400 AND 800 FOR THE STANDARD DEVIATION OF  $U$ .

500  
THE TRUE COMPONENT OF Y, NAMELY  $300 + 0.3X$ , IS AS FOLLOWS 6600.78 3892.53 1739.04 5048.28

	4027.25	5206.29	2319.33	5327.73	1772.16	4955.13	6056.37	2595.33	2130.96
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	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2
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Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100
1997	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100

CONSUMER EXPENDITURES Y ARE OBTAINED BY ADDING THE TRUE COMPONENT TO THE RANDOM TERM U.

THE ABOVE FOUR SETS OF VALUES ARE SHOWN IN THE FOLLOWING TABLE

X(FAMILY INCOME) 300+.3X

21002.6	6600.78	725.2	7325.98
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11975.1	3892.53	345	4237.53
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4796.8	1739.04	-710.85	1028.13
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15827.6	5048.28	-729.45	4318.83
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12407.5	4022.25	-612.35	3409.9
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16354.3	5206.29	375.85	5582.14
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6731.1	2319.33	890.1	3209.43
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16759.1	5327.73	130.15	5457.88
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4907.2	1772.16	654.1	1118.06
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15517.1	4955.13	259.75	5214.88
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Year	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100
1918	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100

7651.1  
2595.33  
-189.2  
2784.53

6103.2	2130.96	375.05	1755.91
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3559.4  
1367.82  
538.2  
829.62

12934.2	4180.26	580.15	3600.11
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17667.6	5600.28	86.7	5686.98
		-	

11340.3	3702.09	477.8	3224.29
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20903.7  
6571.11  
394.75  
6365.86

3955	1486.5	839.15	647.35
556	1000	-	1000
557	1000	-	1000

Year	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100
Population	1969.5	1970.5	1971.5	1972.5	1973.5	1974.5	1975.5	1976.5	1977.5	1978.5	1979.5	1980.5	1981.5	1982.5	1983.5	1984.5	1985.5	1986.5	1987.5	1988.5	1989.5	1990.5	1991.5	1992.5	1993.5	1994.5	1995.5	1996.5	1997.5	1998.5	1999.5	2000.5	2001.5	2002.5	2003.5	2004.5	2005.5	2006.5	2007.5	2008.5	2009.5	2010.5	2011.5	2012.5	2013.5	2014.5	2015.5	2016.5	2017.5	2018.5	2019.5	2020.5	2021.5	2022.5	2023.5	2024.5	2025.5	2026.5	2027.5	2028.5	2029.5	2030.5	2031.5	2032.5	2033.5	2034.5	2035.5	2036.5	2037.5	2038.5	2039.5	2040.5	2041.5	2042.5	2043.5	2044.5	2045.5	2046.5	2047.5	2048.5	2049.5	2050.5	2051.5	2052.5	2053.5	2054.5	2055.5	2056.5	2057.5	2058.5	2059.5	2060.5	2061.5	2062.5	2063.5	2064.5	2065.5	2066.5	2067.5	2068.5	2069.5	2070.5	2071.5	2072.5	2073.5	2074.5	2075.5	2076.5	2077.5	2078.5	2079.5	2080.5	2081.5	2082.5	2083.5	2084.5	2085.5	2086.5	2087.5	2088.5	2089.5	2090.5	2091.5	2092.5	2093.5	2094.5	2095.5	2096.5	2097.5	2098.5	2099.5	2100.5
Area	1969.5	1970.5	1971.5	1972.5	1973.5	1974.5	1975.5	1976.5	1977.5	1978.5	1979.5	1980.5	1981.5	1982.5	1983.5	1984.5	1985.5	1986.5	1987.5	1988.5	1989.5	1990.5	1991.5	1992.5	1993.5	1994.5	1995.5	1996.5	1997.5	1998.5	1999.5	2000.5	2001.5	2002.5	2003.5	2004.5	2005.5	2006.5	2007.5	2008.5	2009.5	2010.5	2011.5	2012.5	2013.5	2014.5	2015.5	2016.5	2017.5	2018.5	2019.5	2020.5	2021.5	2022.5	2023.5	2024.5	2025.5	2026.5	2027.5	2028.5	2029.5	2030.5	2031.5	2032.5	2033.5	2034.5	2035.5	2036.5	2037.5	2038.5	2039.5	2040.5	2041.5	2042.5	2043.5	2044.5	2045.5	2046.5	2047.5	2048.5	2049.5	2050.5	2051.5	2052.5	2053.5	2054.5	2055.5	2056.5	2057.5	2058.5	2059.5	2060.5	2061.5	2062.5	2063.5																																					

9406	3121.8	246.05	3367.85
9407	3121.8	246.05	3367.85
9408	3121.8	246.05	3367.85
9409	3121.8	246.05	3367.85
9410	3121.8	246.05	3367.85
9411	3121.8	246.05	3367.85
9412	3121.8	246.05	3367.85
9413	3121.8	246.05	3367.85
9414	3121.8	246.05	3367.85
9415	3121.8	246.05	3367.85
9416	3121.8	246.05	3367.85
9417	3121.8	246.05	3367.85
9418	3121.8	246.05	3367.85
9419	3121.8	246.05	3367.85
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9429	3121.8	246.05	3367.85
9430	3121.8	246.05	3367.85
9431	3121.8	246.05	3367.85
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9445	3121.8	246.05	3367.85
9446	3121.8	246.05	3367.85
9447	3121.8	246.05	3367.85
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9459	3121.8	246.05	3367.85
9460	3121.8	246.05	3367.85
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9471	3121.8	246.05	3367.85
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9473	3121.8	246.05	3367.85
9474	3121.8	246.05	3367.85
9475	3121.8	246.05	3367.85
9476	3121.8	246.05	3367.85
9477	3121.8	246.05	3367.85
9478	3121.8	246.05	3367.85
9479	3121.8	246.05	3367.85
9480	3121.8	246.05	3367.85
9481	3121.8	246.05	3367

14512	4633.6	27.65	4681.25
30010	5003	-170.5	5733.5

22010	0303	170.3	6732.3
17505	5505	-60 1	5505 7

17080	3003.8	60.1	3343.7
22002	7261.11	-10.1	7207.04

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2
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	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2
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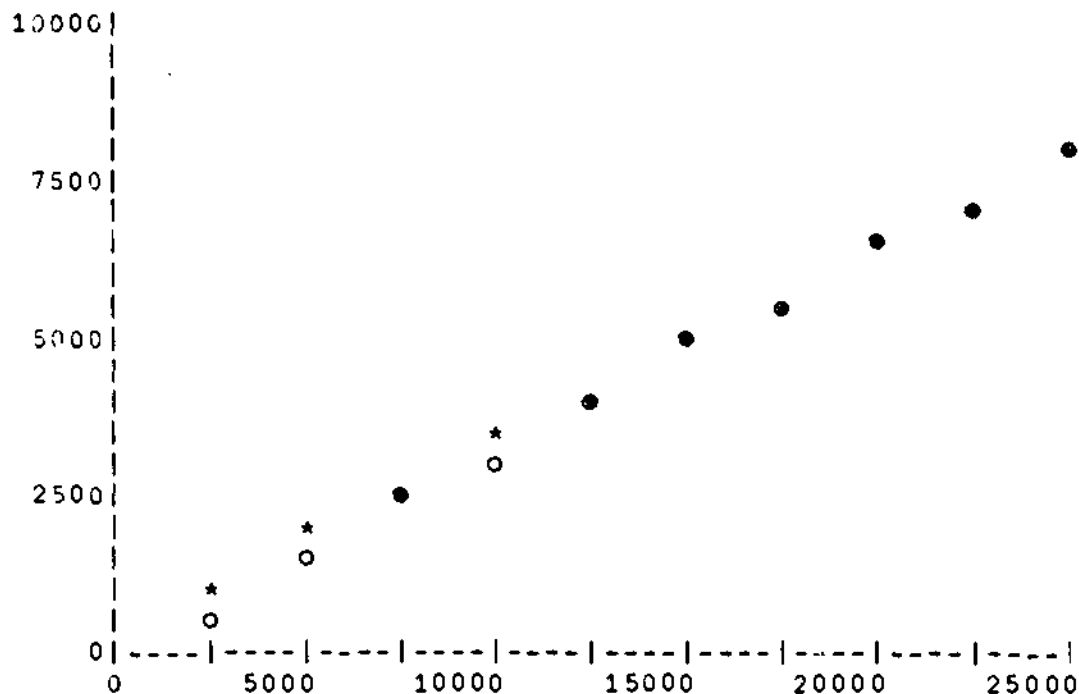
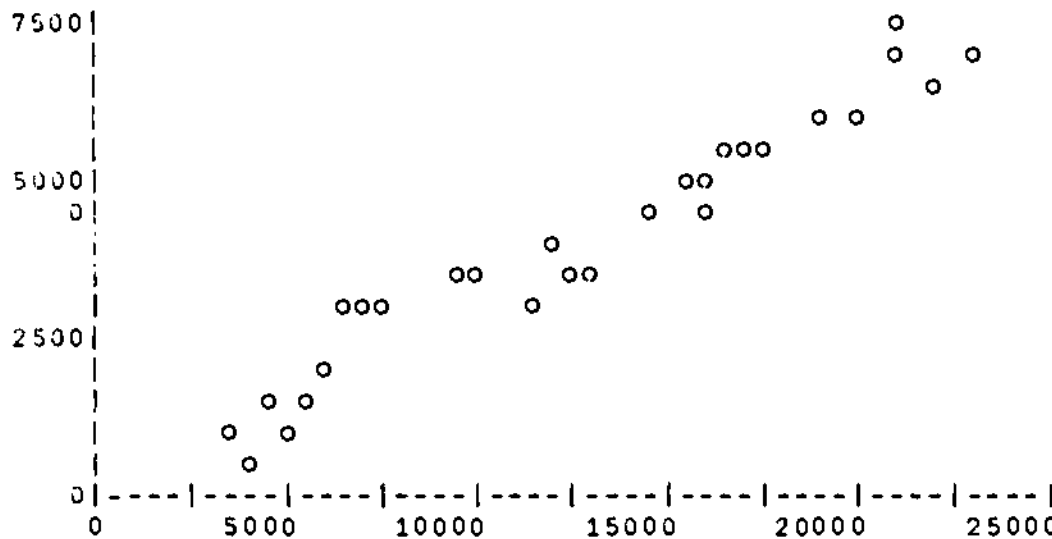
1. The first part of the paper discusses the importance of the role of the state in the development of the economy. It argues that the state should play a leading role in the development of the economy, particularly in the areas of infrastructure, education, and health care. The state should also play a role in the development of the private sector, particularly in the areas of small and medium-sized enterprises (SMEs) and the service sector.

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The second regression model is  $Y = 300 + .3X + U$  where  $U$  is now serially correlated according to the autocorrelation scheme  $U(t) = R \times U(t-1) + E(t)$ .  $U(t)$  is the error term at time  $t$ ,  $U(t-1)$  is the error term at time  $t-1$ ,  $R$  is a constant with absolute value less than or equal to 1, and  $E(t)$  is an error term normally distributed with mean zero and specified variance. This formula generates the last  $n-1$   $U$  terms based on an initial value for  $U$ , called  $U(1)$ , which is selected randomly from the interval  $(-250, 250)$ . The  $Y$  and  $X$  variables are identical to those in the first model. The students are asked to type in the standard deviation of  $E$ , the value of  $R$ , the upper and lower limits of family income, and the size of sample.

Many real life relationships between two variables correspond to our second model and the simulation of observations based on this model should enable the student to gain valuable insights regarding the proper use of empirical data. In reality, the  $U$  term contains the effects of all variables on the dependent variable  $Y$  except the influence of the independent variable  $X$ . Because in the real world a great number of factors influence the dependent variable, the  $U$  term in a regression model could be very important.

It can be shown that when the error term  $U$  is autocorrelated by the above scheme, the estimates of the regression coefficients by OLS are unbiased, but the standard errors of these coefficients will be very large relative to non-autocorrelated  $U$  terms. Hence, hypothesis testing and interval estimation concerning the regression coefficients may not be reliable.

Simulations of  $Y$  (family expenditures) and  $X$  (family income) observations according to our second model are shown below in print outs of programs based on this model. The observations and plottings are displayed in much the same manner as those of the first print out. For both sample sizes of 10 and 30, the value of  $R$  is 1, the standard deviation of  $E$  is 500, and the lower and upper limits of family income are 2000 and 25000, respectively.

IN ORDER TO GENERATE A SET OF N OBSERVATIONS WITH AUTOCORRELATED U TERMS OF THE  
FORM  $U(T)=R \times U(T-1)+E(T)$  YOU WILL BE ASKED TO SUPPLY CERTAIN INFORMATION. PLEASE  
SELECT AN INTEGER BETWEEN 10 AND 30 FOR THE SAMPLE SIZE

□:

10

WHAT IS THE LOWER LIMIT OF THE FAMILY INCOME RANGE?

□:

2000

PLEASE SELECT A NUMBER FOR THE UPPER LIMIT OF FAMILY INCOME

□:

25000

THE 10 INCOME VALUES SELECTED AT RANDOM FROM THE INTERVAL 25000-2000 ARE 16257.7 8888.5  
17361.7 24434.2 11252.9 10928.6 14134.8 9958 24190.4 5512.1

THE ERROR TERMS U ARE DETERMINED BY THE FORMULA  $U(T)=R \times U(T-1)+E(T)$ . THE INITIAL  
VALUE FOR U, DENOTED  $U(1)$  AND SELECTED FROM THE INTERVAL -250 TO 250, IS -47

PLEASE SELECT A NUMBER BETWEEN 200 AND 700 FOR THE STANDARD DEVIATION OF E

□:

500

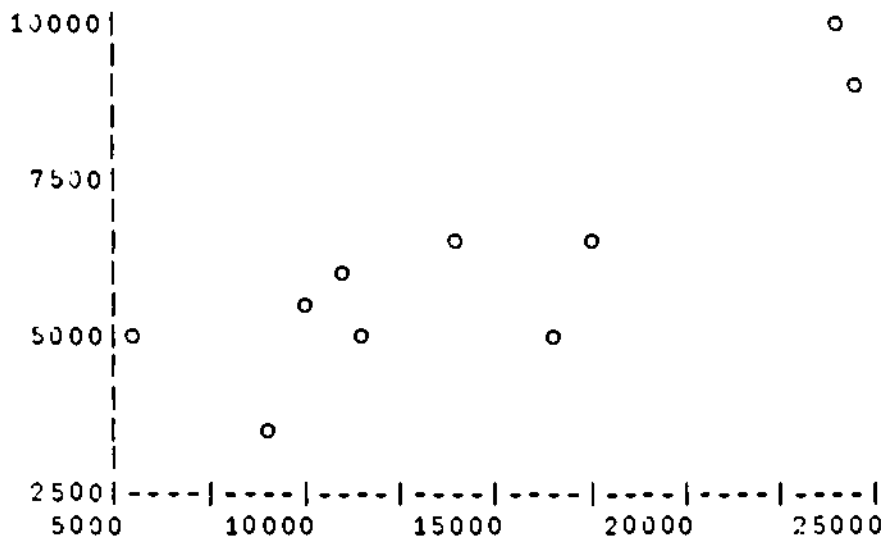
PLEASE SELECT A NUMBER BETWEEN -1 AND 1 FOR THE VALUE OF R

□:

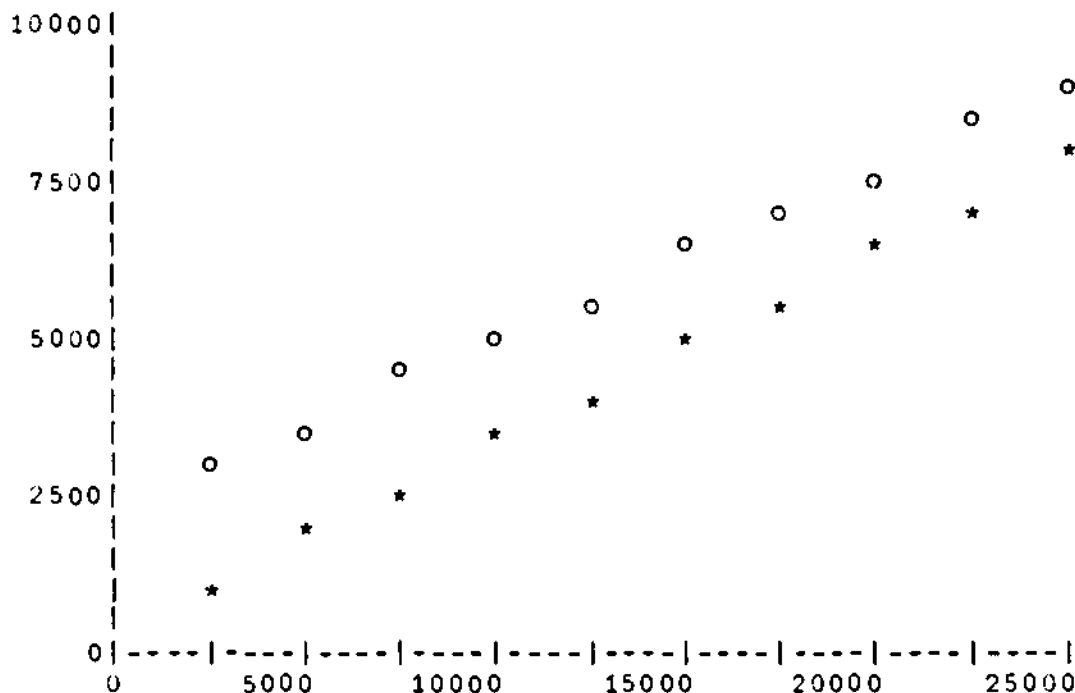
1

THE 10 AUTOCORRELATED U TERMS ARE -47 343 994.7 1394.1 1467.9 2254.7 1952.6 2347.4  
2255.65 2999.25

THE SIMULATED EXPENDITURES ON CONSUMER DURABLES Y ARE FOUND BY ADDING  $300+.3X$   
TO THE U TERMS AND ARE AS FOLLOWS 5130.31 3309.55 6503.21 9024.36 5143.77  
5833.28 6493.04 5634.8 9812.77 4952.88 THESE VALUES ARE PLOTTED AGAINST  
FAMILY INCOME ON THE FOLLOWING PAGE



THE ESTIMATED REGRESSION LINE IS  $Y=2344.418432+0.2686403666X$ , AS COMPARED WITH THE TRUE LINE  $300+0.3X$ . THE ESTIMATED LINE, DENOTED BY O, AND THE TRUE LINE, DENOTED BY \*, ARE PLOTTED BELOW



IF YOU WOULD LIKE TO SIMULATE ANOTHER SET OF OBSERVATIONS WITH A DIFFERENT SET OF INPUT VALUES, PLEASE TYPE YES. OTHERWISE, TYPE NO

IN ORDER TO GENERATE A SET OF N OBSERVATIONS WITH AUTOCORRELATED U TERMS OF THE FORM  $U(T) = R \times U(T-1) + E(T)$  YOU WILL BE ASKED TO SUPPLY CERTAIN INFORMATION. PLEASE SELECT AN INTEGER BETWEEN 10 AND 30 FOR THE SAMPLE SIZE

□:

30

WHAT IS THE LOWER LIMIT OF THE FAMILY INCOME RANGE?

□:

2000

PLEASE SELECT A NUMBER FOR THE UPPER LIMIT OF FAMILY INCOME

□:

25000

THE 30 INCOME VALUES SELECTED AT RANDOM FROM THE INTERVAL 25000-2000 ARE 9856.8 2280.6 3159.2 20048.1 22230.8 12538.6 20117.1 20751.9 23833.9 7338.3 8844.8 12872.1 3350.1 21248.7 19990.6 18916.5 13881.8 9164.5 20634.6 10588.2 18714.1 19912.4 20257.4 20110.2 16370.4 22290.6 23638.4 13628.8 18424.3 11839.4

THE ERROR TERMS U ARE DETERMINED BY THE FORMULA  $U(T) = R \times U(T-1) + E(T)$ . THE INITIAL VALUE FOR U, DENOTED  $U(1)$  AND SELECTED FROM THE INTERVAL -250 TO 250, IS -92.625

PLEASE SELECT A NUMBER BETWEEN 200 AND 700 FOR THE STANDARD DEVIATION OF E

□:

500

PLEASE SELECT A NUMBER BETWEEN -1 AND 1 FOR THE VALUE OF R

□:

1

THE 30 AUTOCORRELATED U TERMS ARE -92.625 -191.425 66.175 405.725 996.925 894.275 -190.225 24.725 50.225 4.925 -338.225 -478.525 24.125 239.725 29.325 19.625 -20.175 -112.025 704.275 153.925 -410.025 -1064.975 -1412.925 -1204.675 -1958.975 -2429.775 -3143.625 -2957.675 -3373.625 -3339.725

THE SIMULATED EXPENDITURES ON CONSUMER DURABLES Y ARE FOUND BY ADDING  $300 + .3X$

TO THE U TERMS AND ARE AS FOLLOWS 3164.415 792.755 1313.935 6720.155 7966.165

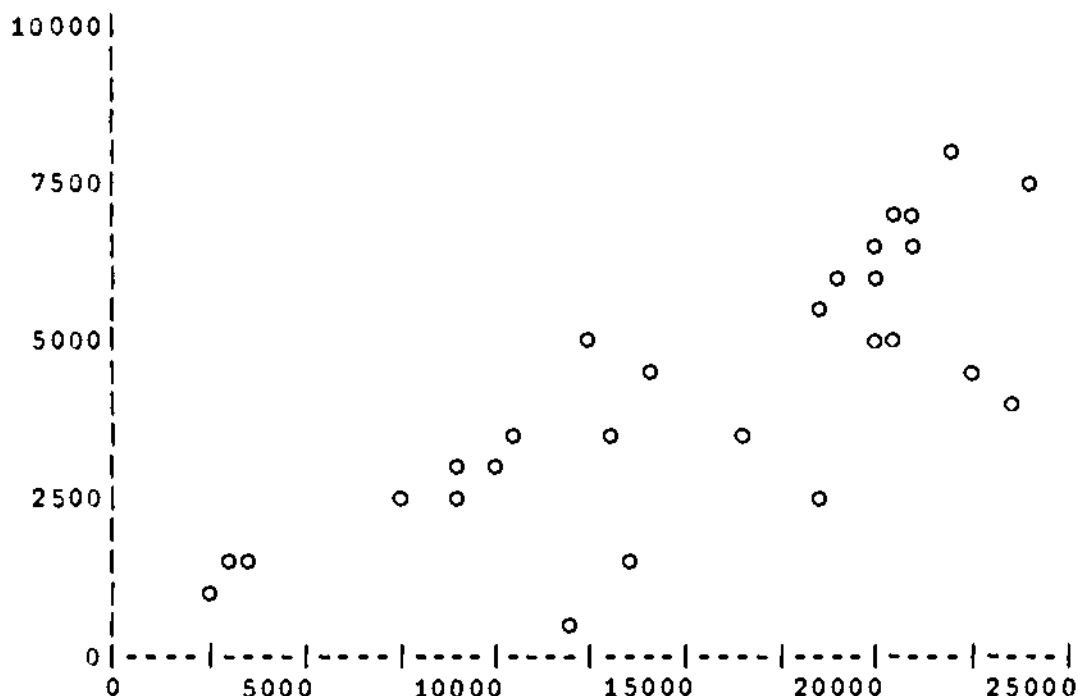
4955.855 6144.905 6550.295 7500.395 2506.415 2615.215 3683.105 1329.155

6914.335 6326.505 5994.575 4444.365 2937.325 7194.655 3630.385 5504.205

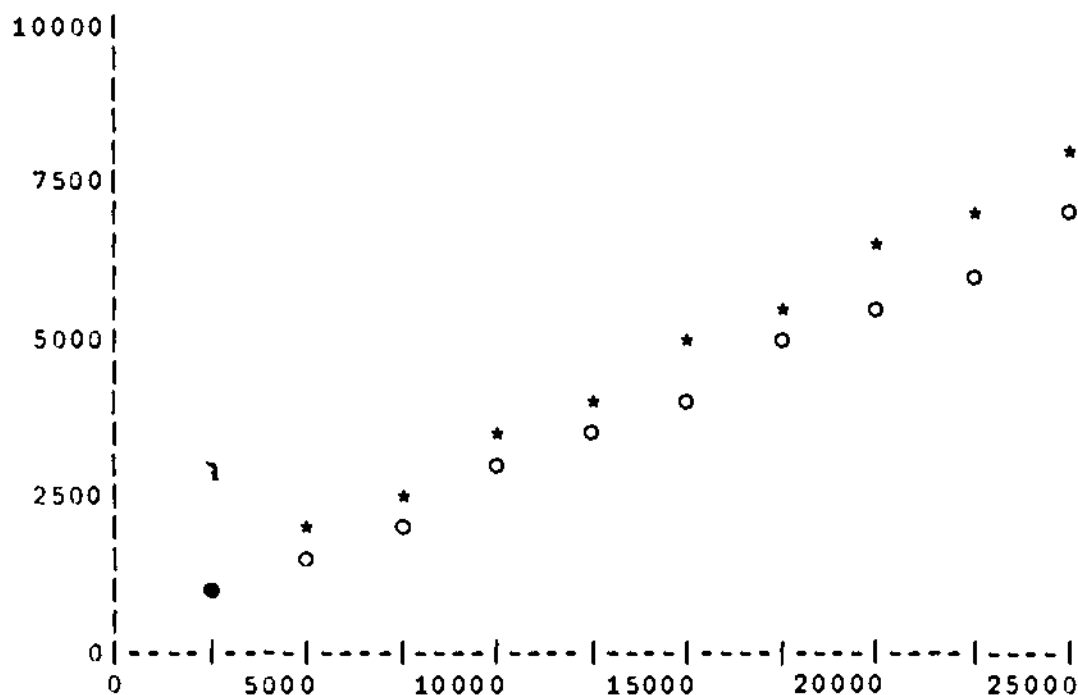
5208.745 4964.295 5128.385 3252.145 4557.405 4247.895 1430.965 2453.665

512.095 THESE VALUES ARE PLOTTED AGAINST

FAMILY INCOME ON THE FOLLOWING PAGE



THE ESTIMATED REGRESSION LINE IS  $Y=145.9801195+0.268972529X$ , AS COMPARED WITH THE TRUE LINE  $300+0.3X$ . THE ESTIMATED LINE, DENOTED BY  $\circ$ , AND THE TRUE LINE, DENOTED BY  $*$ , ARE PLOTTED BELOW



IF YOU WOULD LIKE TO SIMULATE ANOTHER SET OF OBSERVATIONS WITH A DIFFERENT SET OF INPUT VALUES, PLEASE TYPE YES. OTHERWISE, TYPE NO

4. Analysis of Results. With regard to the simulations of model 1 (pp. 5-8), it can be seen that as the sample size increased from 10 to 30, the estimated and true regression lines converged. In general, the students also experienced this same tendency when they executed the program.

Even more revealing is the comparison of the first plottings of both print outs (pp. 6 and 11), and also the second plottings in these print outs (pp. 8 and 13). The first comparison is between the simulated values of Y and X for each model for sample sizes of 10, and the second is a comparison between the simulated Y and X values for sample sizes of 30. It will be noted that the dispersion of the Y observations generated from the autocorrelated model is much wider than that from the non-autocorrelated model--a result that can be expected on the basis of statistical theory. A comparison of the two plottings in the second print out (pp. 11 and 13) also reveals that as the sample size increases, the dispersion of the Y simulated values also increases.

All 16 students in undergraduate econometrics in the spring of 1973 executed these programs enthusiastically. Everyone believed that they learned something about econometrics that they failed to learn from the text and lectures and they expressed a desire to see greater use made of this technique for instructional purposes. The objectives of these two programs, outlined earlier, were largely achieved.

The students mentioned that they learned the following specific things from running these programs: (1) The realization that the estimated line does not coincide with the true regression line; (2) As the size of sample increased, these two lines approached one another; (3) A greater appreciation of the role played by the U term in regression analysis; (4) The nature of randomness, as illustrated by the display of the simulated observations, both graphically and tabularly; and (5) The wide dispersion of the dependent variable as autocorrelation is introduced into regression models.

The main criticisms of the programs were that they are somewhat lengthy, and that not enough input was required by the user.